THE EVERSIBLE REPUGNATORIAL SCENT GLANDS OF INSECTS.

PLATE V.

BY A. S. PACKARD.

While these eversible glands are not found in marine or aquatic Arthropods as Crustacea or Merostomata (Limulus), they are often present in the air-breathing forms, especially insects. In the winged insects they are of frequent occurrence, existing under great variety of form, varying greatly in position, and appearing usually to be in immediate relation with their active volant habits. Their presence is in direct adaptation to the needs and habits of their possessors, and being repellant, warning, or defensive structures, the odors they secret being often exceedingly nauseous, they appear to have been called into existence in direct response to their biological environment. The fact that these singular organs do not exist in marine or aquatic Crustacea suggests that the air-breathing, aerial or volant insects by these eversible glands, usually in the form of simple evaginable hypodermic pouches, are enabled to protect themselves by emitting an infinitesimal amount of an offensively odorous fluid or ether-like spray which charges the air throughout an extent of territory which may be practically illimitable to the senses of their enemies. The principle is the same as in the mephitic sulphuretted oil ejected by the skunks, the slight quantity these creatures give out readily mixing with and charging the atmosphere within a radius of many miles of what we may call the center of distribution.

As is now well known, the very delicate, attenuated highly volatile odors exhaled are perceived by insects with extreme ease and rapidity, the degree of sensitiveness to such scents being enormously greater than in vertebrates, their organs of sense being developed in a corresponding degree. Professors Fischer and Penzoldt, of Erlangen, have recently established the fact that the sense of smell is by far the most delicate of the senses. They find that the olfactory nerve is able to detect the presence of $\frac{1}{2,760,000,000}$ of a grain of mercaptan.* The smallest particle of matter that can be detected by the eye is sodium, when observed by the spectroscope, and this particle is two hundred and fifty times

*Mercaptan is a mercury, belonging to a class of compounds analogous to alcohol, having an offensive garlic odor. Methyl mercaptan is a highly offensive and volatile liquid.

coarser than the particle of mercaptan which can be detected by the nose.

In those Arachnida which are provided with poison glands, these scent glands are absent, but in certain Acarina and Linguatulidæ, which have no poison glands, there are various oil glands, stigmatic glands, as well as scent glands, and in seizing a Thelyphonus with the forceps I have observed it to send out from each side of the body a jet of offensive spray.

We find not infrequently in Myriopods (Polydesmidæ, Julidæ, and Glomeris) repugnatorial or the so-called cyanogenic glands, which are either paired, opening on the sides of the body, or form a single row along the median line of the under side of the body. Leidy describes and figures the spherical glands of *Julus marginatus*, of which there are fifty pairs. These glands have been regarded as modified nephridia, but are more probably coxal glands, and the homologues of the parapodial glands of annelid worms.

True coxal glands occur in *Scolopendrella immaculata* on the 3d to 11th and the last segment, on the inner side of the base of the legs. Homologous glands also occur in the same position in *Campodea staphylinus* (also in *C. cookei* and *C. mexicana*) on the 1st to 8th abdominal segments, and Oudemans has described a pair of eversible sacs on each side of segments 1 to 7 of Machilis. These eversible sacs in the Synapterous insects are evidently modified coxal glands, and are probably repugnatorial as well as respiratory in function.

The apparatus consists of an eversible gland, composed of hypodermic cells, usually retracted by a slender muscle and with an efferent passage, but the glands vary greatly in shape and structure in different insects. In some cases these fœtid glands appear not to be the homologues of the coxal glands, but simply dermal glands.

These repugnatorial glands are of not infrequent occurrence in the lower or more generalized winged insects, and in situation and appearance are evidently the homologues of the coxal glands of the Symphyla and Synaptera.

In the ear-wigs (*Forficula* and *Chelidura*) Meinert has detected a pair of what he calls fœtid glands at the posterior margin of the dorsal plates of the second and third abdominal segments.

Vosseler also describes the same glands as consisting of a retort-shaped sac, in whose walls are numerous small epidermal cells and large single glandular cells provided with an efferent passage, the fluid being forced out by the pressure of the dermal muscles, one

acting specially to retract the gland. The creature can squirt to a distance of five and even ten centimeters (4 inches) a yellowish brown liquid or emulsion with the odor of a mixture of carbolic acid and creosote.

The large eversible dorsal glands of the Blattidæ, since they contain numerous hairs, which, when everted, are fan-like or like tufts, serve, as in the spraying or scent apparatus, to disseminate the odor, might be classified with the alluring unicellular scent glands or *duftapparat* of other insects, as they are by some authors; but as the glands are large and compound they may prove to be the homologues of the coxal glands rather than of the dermal glands.

Evaginable organs in the Blattids were first observed by Gerstæcker in both sexes of Corydia; they are yellowish white, covered with hairs, and are thrust out from between the dorsal and ventral plates of the first and second abdominal segments.

In the cockroach (*P. orientalis*) Minchin detected two pouch-like invaginations of the cuticle, lying close on each side of the middle line of the body between the fifth and sixth tergites of the abdomen. They are lined by a continuation of the cuticle, which forms, within the pouches, numerous stiff, branched, finely pointed bristles, beneath which are a number of glandular epithelial cells. In the male nymph of *P. decorata* he also found beside these glandular pouches "an additional gland, opening by a tubular duct under the intersegmental membrane between the fifth and sixth terga above the glandular pouch of each side, and extending forward into the body cavity. The gland and its duct are proliferations of the hypodermis, and there is no invagination of the cuticle." These eversible glands are most complicated in *Phyllodromia germanica*. While it is absent in the female, in the male it is relatively of enormous size, extending over the sixth and seventh somites, as well as projecting far into the body cavity (Minchin). Haase states that these glands become everted by blood-pressure and give out the well-known disagreeable smell of these insects. He states that in the male of *P. germanica* the dorsal glands in the sixth and seventh abdominal segments are without hairs and produce an oily secretion; they function as odoriferous organs in sexual union.

In the male of another Blattid (*Aphlebia bivittata*) of the Canary Islands, Krauss has detected two yellowish dorsal sacs 1.5 mm. in length, opening out on the seventh abdominal segment, and filled full of long yellowish hairs, the ends directed towards the opening, where they form a thick tuft. These eversible glands lined with hairs appear to be

closely similar to the long slender eversible hairy appendages or scent organs of certain Arctian and Syntomid moths.

I have found the external median wart with lateral lids or flaps in between the fifth and sixth tergites of *Platyzosteria ingens* Scudder, a large wingless Blattid living under the leaf scars of the cocoanut tree in Southern Florida, but was unable to detect them in *Polyzosteria* or in *Blabera* from Cuba, or in another genus from Cordova, Mexico.

In another group of Orthoptera, the Phasmidæ, occur a pair of dorsal prothoracic glands, each opening by a pore and present in both sexes. In the walking-stick, *Anisomorpha buprestoides*, ♂ and ♀, these openings are situated on each side of the prothorax at its upper anterior extremity, situated at the bottom of a large deep pit. When seized it discharged a "milky white fluid from the pores of the thorax, diffusing a strong odor, in a great measure like that of the common Gnaphalium or life everlasting" (Peale in Say's American Entomology, I, p. 84). Boll states that the females when captured "spurt from the prothorax, somewhat after the manner of bombardier beetles, a strong vapor, which slightly burnt the skin; when the females were seized by the males a thick fluid oozed from the same spot." Scudder describes these glands in another Phasmid (*Autolyca pallidicornis*) as two straight, flattened, ribbon-like bodies, with thick walls, broadly rounded at the end, lying side by side and extending to the hinder end of the mesothorax. In *Anisomorpha buprestoides* the glands are of the same size and shape (Scudder, Psyche, I, p. 137). In *Diapheromera femorata* the repugnatorial foramina are very minute, and the apparatus within consists of a pair of small obovate or subfusiform sacs, one on each side of the prothorax, about 1 mm. in length, with a short and very slender duct opening externally at the bottom of the pit (Scudder).

In the Mantidæ these seem to be genuine coxal glands, as there is a pair situated between the coxæ of the first pair of legs. An evaginable organ like a wart, with a glandular appearance, occurs on the hind femora of the Acrididæ in a furrow on the under side into which the tibia fits, about one-fourth from the base (Psyche, III, p. 32).

In the male cricket, the anal odoriferous glands are small lobes opening into a reservoir on each side of the rectum (Dufour). Homologous glands also occur in the Coleoptera and Lepidoptera, and may prove to be coxal glands.

Most Hemiptera or bugs send out a fœtid or nauseous odor due to a fluid secreted by a single or double yellow or red pear-shaped gland, situated in the middle of the mesothoracic segment, and opening be-

tween the hinder or third pair of coxæ. In *Belostoma* Leidy describes these glands as consisting of two rather long cœcal tubes situated in the metathorax, beneath the other viscera, extending backwards into the abdomen, and opening between the coxæ of the third pair of legs. Some bugs, however, emit an agreeable odor, that of Lysomastes resembling that of a fine bergamot pear (Siebold). The fluid given out by the European fire-bug (*Pyrrhocoris apterus*) has a sweetish smell, like ether. In the nymph there are three pairs of dorsal glands, on abdominal segments 2–5, which are atrophied in the mature insect. In the bed-bug, the nymph has three odoriferous glands, each with paired openings in the three basal abdominal segments respectively; and situated on the median dorsal line, being arranged transversely at the edge of the tergites, but after the last molt these are aborted, aud replaced by the sternal metathoracic glands (Künckel).

Certain beetles are endowed with eversible repugnatorial glands. *Eleodes gigantea* and *E. dentipes* of both sexes are said by Gissler to possess these glands. When teased "they stand on their anterior and middle legs, holding the abdomen high up and spurting the contents of the glands right and left." The glands (Plate V, Fig. 1) are two reddish brown, somewhat bilobed sacs, and extend from the base of the last up to the middle of the second abdominal segment, with an average length of 6.5 mm. The liquid stains the human skin, has an acid reaction, with a peculiar, "intensely penetrant odor, causing the eye to lachrymate. It is soluble in water, alcohol and ether. Boiled with concentrated sulphuric acid and alcohol an ethereal aromatic vapor is produced, indicating the presence of one or more organic acids, though neither formic or acetic acid could be detected. Williston has observed the same habits in seven other species of *Eleodes*, all ejecting a pungent vile-smelling liquid, one species (*E. longicollis*) ejecting a stream of fluid from the anal gland, backwards sometimes to the distance of ten centimeters or more, and he regards these beetles as "the veritable skunks of their order." Leidy briefly describes the odoriferous glands of *Upis pennsylvanica*.

Glands like those of *Eleodes* found in *Blaps mortisaga* are described in detail by Gilson (Plate V, Fig. 2). They form two pouches or cuticular invaginations situated in the end of the abdomen on the sides of the end of the intestine and unite on the median line underneath the genital organs, forming a very short tube with a chitinous wall, continuous with the cuticle of the last abdominal segment. Into each pouch open a large number of fine slender lobules varying in shape, giving a vil-

lous aspect to the surface. These lobules are composed of as many as fifty unicellular glands, each of which is composed of four parts: (1) A radiated vesicle, (2) a central sac, giving rise (3) to a fine excretory tube, and (4) a sheath near the origin of the excretory tube. These are all modifications of the cytoplasm of the cell with its reticulum; the nucleus with its chromosomes is also present, but situated on one side of the central sac. The fine excretory tubules form a bundle passing down into the mouth of each lobule.

Similar glands, though usually smaller, which have not been carefully examined, occur in *Carabus* (Fig. 3) and *Cychrus*, which eject from the vent a disagreeable fluid containing butyric acid (Pelouse . The bombardier beetle *Brachinus*, with its anal glands, ejects a jet of bluish vapor accompanied with a considerable explosion, which colors the human skin rust red; it is caustic, smells like nitrous acid and turns blue paper red. Westwood states that individuals of a large South American *Brachinus* on being seized "immediately began to play off their artillery, burning and staining the flesh to such a degree that only a few specimens could be captured with the native hand, leaving a mark which remained for a considerable time." The fluid ejected by another species in Tripoli, blackened the fingers of the collector. "It is neither alcaline nor acid, and it is soluble in water and in alcohol" (Kirby and Spence, IV, p. 149).

Species of other genera (*Agonum*, *Pheropsophus*, *Galerita*, *Helluo*, *Paussus*, *Ozæna*) are also bombardiers, though less decidedly so than *Brachinus*. A Paussid beetle (*Cerapterus*) ejects explosively a fluid containing free iodine (Loman), while *Staphylinus*, *Stenus*, *Ocypus olens*, *Lacon*, etc., have similar anal fœtid glands, the liquid being more or less corrosive. The secretion of *Mormolyce phyllodes* is so corrosive that it is said to paralyze the fingers for twenty-four hours after (Cuénot).

The two pairs of remarkably large soft eversible forked orange yellow glands of the European genus *Malachius*, are thrust out from the side of the first and the third thoracic segments. They are everted by blood-pressure, and retracted by muscles. The larva of *Hydrophilus piceus* ejects by the anus a black fœtid fluid.

Claus has shown that the larva of *Lina populi* and other Chrysomelidæ possess numerous minute eversible glands in each of the warts on the upper surface of the body, each gland containing a whitish repellant fluid smelling like the oil of bitter almonds and containing salicylic acid derived from its food plant, which issues as pearl-like drops.

Candèze thinks the fluid may contain prussic acid. The fluid is secreted by a variable number of glandular cells, each provided with an efferent duct. The larvæ of sawflies, notably *Cimbex americana*, also eject droplets of a clear fluid from their skin.

In this connection it may be mentioned that though there are no special glands present, many beetles emit drops of blood from the femoro-tibial joints of their legs as a means of defence. Such are the oil beetles (*Meloë*), *Cantharis*, *Lytta*. The cantharadine secreted by these beetles, according to Beauregard, is an efficient means of defense as birds, reptiles and carnivorous insects will not usually attack them. This substance is formed in the blood and also in the genital organs, and is so extremely caustic that scavenger insects which feed upon their dead bodies will leave untouched the parts containing cantharadine, and if May-beetles or Mole Crickets are washed with the blood of Meloë or with cantharidate of potassa, it will for several days render them safe from the attacks of the carabids which usually prey upon them. The eggs even after deposition are strongly vesicant, and are thus free from the attacks of egg-eating insects (Cuénot). The Coccinellidæ are also protected by a yellow mucilaginous disagreeable fluid oozing out of the sides of the thorax; in our common two-spotted Lady-bird (*C. bipunctata*) the yellow fluid is disagreeable, smelling like opium.*

The Dytiscidæ eject from the anus a colorless disagreeable fluid, while these beetles, and especially the Gyrinidæ, when captured send out a milky fluid which appears to issue from the joints of the body. The Silphidæ throw out both from the mouth and vent a fœtid liquid with an ammonial odor. They possess but a single anal gland, the reservoir opening on one side of the rectum (Dufour).

More agreeable secretions, but probably formed by similar glands, is the odor of rose or hyacinth given out by Cicindelæ, or the rose fragrance exhaled by the European *Aromia moschata*.

Other malodorous insects have not yet been investigated; such are the very persistent odors of lace-winged flies (*Chrysopa*).

The anal glands consist, according to Meckel and also Dufour, of two long simple flexuous cœca with reservoirs having two short excretory ducts situated near the anus (Siebold).

Many caterpillars, as our subjoined list will show, are very well protected by eversible repugnatorial glands situated either in the under or upper side of the body. Since the time of DeGeer (1750) the fork-

* Lutz has found that the blood in Coccinellidæ passes out through a minute opening situated at the end of each femur. (Zool. Anzeiger, June 24, 1895.)

tailed larva of *Cerura* has been known to throw out a secretion, which was described by Bonnet in 1755 as a true acid, sharp, sour and biting. This spraying apparatus in *Cerura* (*Harpyia*) *vinula* has been well described by Klemensiewicz (Plate V, Fig. 4), though Rengger in 1817 noticed the general form of the secretory sac, and that it opens out in two muscular evertible tubes, out of which the secretion is ejected.

The fork-tailed larva of *Macrurocampa marthesia*, which is much like that of *Cerura*, when teased sends out a jet of spray to the distance of nearly an inch from each side of the neck. While examining the very gaily colored and heavily spined caterpillars of *Schizura concinna* I observed that when a fully grown one was roughly seized with the forceps or fingers it sent out a shower of spray from each side of the prothoracic segment, exactly like that of *Cerura* and *Macrurocampa*.

In the European *Cerura vinula* the apparatus consists of a single sac, which opens by a narrow transverse slit on the under side of the neck, out of which is rapidly everted four lateral tubes, two on each side (Plate V, Fig. 4 *t*), which are withdrawn within the opening by the contraction of several fine muscles. The apparatus in the American *C. multiscripta* is as in the European *C. vinula*. In a living specimen the large secretory sac was seen to be of the same size and shape as in *Macrurocampa*, and of the color of raw silk. The sac when disturbed extends back to a little behind the middle pair of legs, and is nearly two-thirds as wide as the body. The caterpillar sent out the fluid when handled, but I could not make it spray.

In the larva of *Macrurocampa marthesia* the cervical or secretory gland (Plate V, Fig. 5) is situated in the first and second thoracic segments, extending to the hinder edge of the latter and lying between the nervous cord and the œsophagus and proventriculus, and when empty the bulk of it lies a little to one side of the median line of the body. It is partly held in place by small tracheæ, one quite large branch being sent to it from near the prothoracic spiracle. The short large duct leading from it to the transverse opening in the membrane between the head and prothoracic segment is a little narrower than this opening, and is kept distended by tænidia or a series of short spiral threads which are pale, not honey-yellowish in color. This duct lies on one side of the prothoracic ganglion resting just under the commissures passing up to the brain; it is also situated between the two salivary ducts.

The very distensible sac (Plate V, Fig. 5) is rendered elastic by a curious arrangement of the cuticle, the tænidia of the duct itself being represented by very thickly scattered irregular separate, sinuous

chitinous ridges which stand up from the cuticular lining of the wall of the sac (Plate V, Fig. 6). The secretory cells of the walls of this sac in *Cerura vinula* are said by Klemensiewicz to be large hexagonal cells, resembling those of silk glands, having like them large branched nuclei.

The fluid thrown out is said by Poulton to be formic acid; it causes violent effervescence when allowed to fall upon sodium-bicarbonate, and colors blue litmus paper red.

In the caterpillar of *Astyanax archippus* (*Limenitis disippus*) a dark bladder-like sac is everted, but the lateral tubes appear to be wanting and no spray is sent out; it occurs in the larvæ of many Nymphalidæ, and other butterflies and moths.

Scudder tells me that these glands are generally present in the larvæ of butterflies, including the present species, but as I observed it repeatedly and with some care in this caterpillar I will record my observations. A larva which had hibernated was found May 11 at Providence on a leaf of the wild cherry; its length was 12 mm. I could not but be struck with the protective resembance of the creature when curled up to a mass of birds' droppings.

While examining the caterpillar, my attention was called to a whitish mass with a black outer edge, situated on the under side of the prothoracic segment just behind the head, and in front of the first pair of legs. On removing this mass with the needle I found under it a large low conical eversible soft tubercle covered with short hairs. On rupturing the gland with a needle a little fluid exuded from it. When at rest the gland is retracted within a transverse oval opening. No odor appears to be given out by the fluid, as tested by four persons.

The caterpillar when at rest was experimented on, with the following result. On rudely touching it with the point of a needle, it turned the head on one side and suddenly evaginated the gland to its fullest extent, but no fluid could be seen. On teasing it still further the caterpillar would angrily turn its head over upon its back, so that the hirsute gland would be directed upwards. It then, on being let alone, gradually, but rather rapidly retracted the gland, the thick, rather swollen lips forming a narrow transversely oval opening, which would be easily overlooked.

The gland is bladder-like and of simple bag-like shape, without the pair of diverging siphon-like tubes seen in *Cerura* and *Pheosia*, and it is probable that the fluid is not ejected in a stream or spray, but simply exudes from the gland, in which no opening could be detected.

The gland is of the same dark brown color as the skin of the caterpillar itself, and not light in tint as in *Cerura*, *Pheosia*, etc.

While describing the living larva of *Perophora melsheimerii* my attention was called to some small singular sternal tubercles on the two hinder thoracic segments; but I did not, to my regret, then carefully examine them. On farther examination of two alcoholic specimens, however, I find that the tubercles guard the lips of an eversible gland. They are most distinct on the third thoracic segment, where there are to be readily found four dark prominent papillæ, two on each side of the median line of the body, directly behind the base of the legs. The heads of the papillæ are dark and finely granulated. The two tubercles on each side touch each other; they are probably modified piliferous warts. These four papillæ enclose a square area in the middle of which are the lips, arranged transversely, of the mouth of an eversible gland. These organs are also present on the second segment, and are of the same degree of development. Whether there is the opening of a functional sternal eversible gland on the first thoracic segment I am uncertain, as I have been unable in my two alcoholic specimens (one of which had died and shrivelled up) to detect any traces of lips. On this segment the base of the legs are close together, the basal joints being large and closely contiguous. There are no tubercles developed like those on the second and third segments, and in the material at my disposal I have been unable to find an opening. It is not improbable, however, that such a gland with lips once existed in the ancestors of this and of *Lacosoma*, for in *Nola*, which is a member of a family probably much later in appearance, there are two well developed sternal glands. In several Notodontians one is well developed on the under side of the first thoracic segment, while there are none behind. Probably in the Perophorinæ, owing to the modifications of the body, due perhaps to their constructing a case and thus causing some change in the movements of the first pair of legs, they are much nearer together than usual in larvæ not thus adapted to living in cases.

In *Lacosoma* homologous papillæ are present in the corresponding segments, but whether the external opening of the gland is present I am unable as yet to state. On the third thoracic segment there are four tubercles present in the same general position as in Perophora. The anterior pair, however, are very small, and (antero-posteriorly) remote from the hinder pair. The latter are much larger than the front pair and in the form of small, rather slender papilliform tubercles, and armed at the end with several crowded spine-like granulations. Between them is to be seen in my single alcoholic specimen a depression, but I cannot detect any lips or any opening. On the second thoracic

segment is only a single pair of papillæ; the anterior pair being obsolete, and I cannot detect any opening to a gland.

On the first thoracic segment, the legs are closely contiguous at their broad expanded bases. Directly behind the legs and in the median line of the body is a minute area bearing two minute tubercles, but no opening near them is visible.

It is possible, though careful observations on the living larvæ are needed, that the openings of the repugnatorial glands in Lacosoma are closed from disuse, and that the glands themselves only exist in a rudimentary state. It is interesting, however, to find these glands in this family, and to find that they appear obsolete (at least the external openings in *Lacosoma*), while the glands are functionally active in *Perophora*, a genus so nearly allied. It will be interesting to ascertain whether these glands are present in the true sackworms, or Psychidæ. We should hardly, however, expect to find them developed, since these caterpillars are in closer quarters, the sacks being smaller and more tubular, and there seems to be little need of active repugnatorial glands in creatures otherwise so well protected from attack.*

The caterpillars of the swallow-tailed butterflies (*Papilio*, *Doritis* and *Thais*), as is well known when irritated thrust out from a transverse slit on the upper part of the prothoracic segment, a large orange-yellow V-shaped fleshy tubular process (the *osmeterium*), from which is diffused a more or less melon-like but disagreeable, in some cases, an insufferable, odor; the secretion is acid and reddens litmus paper. The mechanism has been described and figured by Klemensiewicz.

When at rest or retracted the osmeterium lies in the upper part of the body in the three thoracic segments, and are crossed obliquely by several muscular bundles attached to the walls of the body, and by the action of these muscles the evagination of the osmeterium is strongly promoted. After eversion the tubes are slowly retracted by two slender muscles inserted at the end of each fork or tube, and arising from the sides of the third segment behind the head, crossing each other in the median line (Plate V, Fig. 7, *r. m.*). The secretion is formed by an oval mass of glandular cells at the base of the forks; in the glandular mass is a furrow-like depression about which the secretory cells are grouped. The secretion collects in very fine drops on the side of each furrow opposite the glandular cells.

According to C. D. Ash the larva of an Australian Notodontid

* After an examination of microscopic sections of two young larvæ of *Thyridopteryx* I am unable to detect them.

(*Danima banksii* Lewin) protrudes from the under side of the prothoracic segment a y-shaped red organ like that of *Papilio*; no fluid or odor is given out.

The showy caterpillars of *Orgyia* and its allies have a conspicuous coral-red tubercle on the back of the sixth and also the seventh abdominal segment, which on irritation are elongated, the end of the tubercles being eversible. When at rest the summit is crateriform, but on eversion the end becomes rounded and conical. These osmeteria are everted by blood pressure, and retracted by a muscle. Plate V, Fig. 9 represents a section of an osmeterium of *Orgyia leucostigma* when retracted by the muscle (*m*); at the bottom of the crater are the secreting or glandular cells (*gc*), being modified hypodermal cells. These doubtless serve as terrifying organs to ichneumons and other insect enemies, and though we have been unable to detect any odor emanating from the tubercles, yet doubtless they give out a scent perceived by and disagreeable to their insect assailants.

In the Hemileucidæ there are two pairs of lateral osmeteria, which, however, are not highly colored (Pl. V, Fig. 10). In *Megalopyge* (*Lagoa*) there is a lateral row of singular pale permanently everted processes which appear to be the homologues of the osmeteria of larvæ of other lepidopterous families.

In the caterpillars of certain blue butterfles (Lycænidæ) is an internal osmeterium, being a very minute sac which is everted from a transverse slit on the top of the seventh abdominal segment. Its function is quite the opposite of those of the caterpillars of other families since the sac exudes a sweet fluid very attractive to ants, which may be diffused more widely by the delicate spinulose bristles crowning the summit. W. H. Edwards states that in several species of Lycæna, besides that on the seventh abdominal segment, there is on the eighth segment a pair of minute dorsal evaginable tubercles.

In certain of the butterflies, the *Heliconidæ* (*Colænis*, *Heliconius*, *Euides* and *Dione*), there is thrust from the end of the abdomen a pair of large irregular rounded evertible glands, which give out a disagreeable odor, and are consequently repellant, and which seem to be the homologues of the odoriferous glands of other butterflies.

The large soft rounded evertible glands, looking like puff-balls or a rounded pudding (Pl. V, Fig. 12) are everted, when the butterflies are roughly seized, from the dorsal side of the penultimate segment of the abdomen. The males possess two smaller tubercles on the inside of the anal claspers or lobes. Müller also detected, in the females of vari-

ous species of the Heliconidæ enumerated above, a pair of club-shaped processes like the balancers of flies, which are thrust out on each side of and under the odoriferous puff-balls of the hinder edge of the penultimate segment (Pl. V, Fig. 13). The club or head is armed with hairs or bristles, which in *Heliconius* are like the scales of a butterfly.

A pair of small ramose odoriferous glands are said by Siebold, who regarded them as alluring glands, to occur in *Argynnis*, *Melitæa* and *Zygæna*, to be situated near the orifice of the oviduct, and Scudder has detected them near the anus of the female pupa of *Danais archippus*. The appearance of the odoriferous glands in the pupa of *Vanessa io* is well shown by Jackson (Pl. V, Fig. 14). They develop as two tubular ingrowths of the hypodermis, perfectly distinct one from the other, each having its own separate aperture to the exterior. In Fig. 14 the condition of parts is nearly as in the imago, the glands being situated below the rectum and opening of the oviduct. In both sexes of another Brazilian butterfly (*Didonis biblis*) on the median line of the abdomen between the fourth and fifth segments are two roundish vesicles covered with short gray hairs, which emit a disagreeable smell.

It is possible that the dark green fluid in *Parnassius*, secreted by an evaginable gland and which is moulded into shape by the scimetar-shaped *peraplast* (Scudder), is formed by the homologues of the anal glands of other butterflies.

Distribution of repugnatorial or alluring scent Glands in Insects.*

The names of the discoverers of the glands are enclosed in parenthesis.

A. Larval Insects.

a. Prothoracic sternal. Phryganea.

b. Prothoracic sternal, discharging a lateral jet of spray; with a single large internal sack.

LEPIDOPTERA.

Super-family Tineina.

Hyponomeuta evonymella (*Schaeffer*).

* Embryonic or temporary glands, the "pleuropodia" of Wheeler, viz., the modified first pair of abdominal legs, occur in *Œcanthus*, *Gryllotalpa*, *Xiphidium*, *Stenobothrus*, *Mantis* (occasionally a pair on the second abdominal segment, Graber); *Blatta*, *Periplaneta*, *Cicada*, *Zaitha*, *Hydrophilus*, *Acilius*, *Melolontha*, *Meloë*, *Sialis*, *Neophylax*. (See Wheeler, Appendages of the First Abdominal Segment, etc., 1890.)

Family NOCTUIDÆ.

Bryophila (*Rogenhofer*).
Cucullia formosa (*Rogenhofer.*)
Cucullia scrophulariæ (*Rogenhofer*).
Habrostola (*Rogenhofer*).
Cleophana lineariæ (*Rogenhofer*).
Catocala, sp. (*Poulton*).
Aporia cratægæ (*Goossens*).
Aplecta nebulosa (*Goossens*).
Leucania staminea (*Goossens*).
Leucania hispanica (*Goossens*).
Leucania nonagrioides (*Goossens*).
Plusia gamma (*Schaeffer*).

Family NOTODONTIDÆ.

Pheosia rimosa (*Packard*).
Schizura concinna (*Packard*).
Danima Banksii (*Ash*). (Australia, Ent. Month. Mag., Sept. 1892).
Macrurocampa marthesia (*Packard*).
Heterocampa pulverea (sends out vapor from neck, *Riley*, in conversation).
Cerura vinula Goedart (*Schaeffer*).
Cerura furcula (*Poulton*).
Cerura borealis (*Packard*).
Cerura multiscripta (*Packard*).

Superfamily RHOPALOCERA.

Family NYMPHALIDÆ.

Limenitis disippus (*Scudder*).
Astyanax archippus (*Scudder, Packard*).
Argynnis cybele (*Scudder*).
Vanessa io (*Klemensiewitz*).
Melitæa artemis (*Walsingham*).
Melitæa sp. (*Rogenhofer*).
Vanessa sp. (*Rogenhofer*).
Argynnis sp. (*Goossens*).
"Larvæ of many Satyrids." (*Goossens*).

c. Prothoracic, dorsal; sending out a v-shaped odoriferous organ (Osmeterium).

Family PAPILIONIDÆ—all the species, as a rule.

d. Thoracic sternal, evaginable glands.

Family PEROPHORIDÆ.

Lacosoma chirodota (*Packard*).
Perophora melsheimerii (*Packard*).

Family NOLIDÆ.

Nola strigula (*Goossens*).
Nola ovilla (*Packard*).
Nola cucullatella (*Chrétien, Packard*).

Order HYMENOPTERA.

Family TENTHREDINIDÆ.

Crœsus septentrionalis (*Poulton*). **Cimbex americana** (*Packard*).
Crœsus varus (*Poulton*).

e. Lateral abdominal partly eversible glands emitting neither moisture nor odor, but flesh-colored.

Superfamily TINEINA.

Phyllocnistis? (*Chambers*). Eight pairs.

Family HEMILEUCIDÆ.

Hyperchiria io (*Dimmock, Packard*). Two pairs, viz., on 1st and 7th segment.
Hyperchiria? sp. Mexico. (*Packard*).
Hemileuca yavapai (*Packard*).
Hemileuca maia (*Packard*).
Pseudohazis eglanterina (*Packard*).

f. Lateral abdominal permanently everted glands, not known to secrete a fluid, nor to be odoriferous.

Family LAGOIDÆ.

Lagoa crispata (*Packard*).

g. Medio-dorsal partly eversible glands, emitting a spray of liquid and an odor (?), and colored coral-red or orange-yellow (P. auriflua), but usually in the European species yellowish.

Family LIPARIDÆ.

Orgyia antiqua.
Orgyia ericæ (*Packard*).
Orgyia gonostigma (*Klemensiewicz*).
Orgyia gulosa (*Riley*).
Orgyia vetusta (*Riley*).
Parorgyia clintonii (*Coquillett, Riley*).
Dasychira fascelina (*Klemensiewicz, Packard*).
Leucoma salicis (*Klemensiewicz*).
Laria rossii (*Packard*).
Psilura monacha (*Poulton*).
Ocneria dispar (*Klemensiewicz, Packard*).

Parorgyia leucophæa (*Riley*).
Parorgyia paralella (*Packard*).
Dasychira pudibunda (*Poulton, Packard*).
Liparis detrita (*Klemensiewicz*).
Liparis auriflua (*Klemensiewicz, Packard.*)
Liparis rubea (*Klemensiewicz*).

All Liparidæ except *Demas* (*Poulton*).

In the following Indian species they have been observed by Mr. Poulton:

Lymantria concolor.
Chœrotricha plana.
Charmidas exclamationis.
Artaxa vitellina.
Artaxa scintillaris.
Artaxa guttata.
Dasychira dalbergiæ.

h. A single median abdominal dorsal gland emitting a fluid attractive to ants, on seventh segment; with a pair of minute index glands on the eighth segment.

Family LYCÆNIDÆ.

Lycæna damon (*Pezold*).
Lycæna bætica (*Guenée*).
Lycæna icarus (*Edwards*).
Lycæna scudderi (*Saunders*).
Lycæna pseudargiolus (*Edwards*).

i. Protrusile organs near the anus.

Myrmeleon larva (*Hagen? Dimmock*).

B. NYMPH OF AMETABOLOUS INSECTS.

a. Paired dorsal glands on abdominal segments 1, 2 and 3.

Cimex lectularius (*Künckel*).

b. The same on abdominal segment 5.

Lachnus strobi (*Gissler*).

C. PUPA OF CERTAIN BOMBYCES.

At anterior end of certain pupæ, internal glands to moisten threads of the cocoon for exit of moth.

D. ADULT INSECTS.

a. Occurring on the prothorax only; strongly repugnatorial, best developed in ♂.

Anisomorpha buprestoides (*Peale, Say, Boll, Scudder*).
Autolyca pallidicornis (*Stål, Scudder*).
Phasma putidum (*Bates*).
Phyllium, sp. (*Scudder*).
Heteropteryx, sp. (*Scudder*).

Diapheromera femoratum (*Scudder*).

Probably in all the species of the family (*Scudder*).

Mantis carolina (*Packard*).

b. Occurring on the pro- and mesothorax, and on the middle of the abdomen orange-yellow fleshy tubercles or evaginations.

Malachius bipustulatus (*Laboulbène, Klemensiewicz*).

Anthocomus equestris *Laboulbène.*

Evæus thoracicus (*Laboulbène*).

c. Segmental eversible glands homologues of the coxal glands of other Arthropods, occurring on all or nearly all the abdominal segments.

Scolopendrella immaculata, coxal glands on third to eleventh and last pair of legs (*Latzel, Haase*).

Campodea staphylinus, a pair of coxal glands on first to eighth abdominal segments.

Campodea cookei (*Packard*).

Campodea mexicana (*Packard*).

Machilis maritima, evertible coxal glands on segments 1–7 (*Oudemans*).

d. Occurring on the under side of the abdomen.

d^1. In the two first abdominal segments.

Corydia carunculigera ♂ and ♀ (*Gerstaecker*).

d^2. Alluring organs situated on the dorsal side of the abdomen, in the sixth, or sixth and seventh, abdominal segment.

Periplaneta americana ♂ (*Minchin*).

Periplaneta orientalis (*Minchin* larva), (*Haase, Packard*).

Periplaneta decorata ♂ nymph (*Minchin*).

Ectoblatta germanica ♂ (*Minchin*).

Ectobia lapponica ♂ (*Minchin*).

Phyllodromia ♂ only (*Minchin*) Haase.

Aphlebia bivittata ♂ (*Krauss*).

Platyzosterea ingens, on seventh segment (*Packard*).

e. At the end of the body.

Colænis julia ♀ (*F. Müller*).

Heliconius apseudes (*F. Müller*).

f. A long ribbon-like pointed gland, everted during sexual excitement by the male, and situated under the sixth to ninth abdominal tergites. Probably alluring glands.

Hadenœcus subterraneus (*Garman, Packard*).

Ceuthophilus maculatus (*Packard*). In this insect the two alluring glands are rounded at rest.

EXPLANATION OF PLATE V.

Fig. 1. Anal eversible glands of *Eleodes*. (After Gissler.)

Fig. 2. Anal eversible glands of *Blaps*. (After Gilson.)

Fig. 3. Anal glands (*agl*) of *Carabus hortensis*; *rs*, reservoir; *d*, excretory duct; *i*, intestine; *r*, rectum. (After Kolbe.)

Fig. 4. Prothoracic spraying apparatus of *Cerura vinula*; *gl*, the gland; *d*, its duct, with tænidia; *t*, the spraying tubes; *m*, muscles; *rm*, retractor muscles. (After Kliemensiewicz.)

Fig. 5. The thoracic glandular sac of *Macrurocampa marthesia; gl*, the glandular sac; *d*, its duct; *e*, peritracheal epithelium; *t*, the spiral threads or tænidia.

Fig. 6. Irregular separate masses of chitinous ridges on the cuticular lining of the wall of the sacs of *Macrurocampa marthesia*.

Fig. 7. Osmeterium (*os*) of the larva of *Papilio machaon* at rest; *rm*, the retractor muscles at the ends; *m*, the numerous oblique muscles; *dm*, dorsal longitudinal muscles; *t*, trachea; *oe*, œsophagus; *gang*, brain; 1, head; 2, 3, 4, thoracic segments.

Fig. 8. Osmeterium (*os*) of one side, enlarged; *g*, glandular portion at the base; *d*, depressions in the cuticula of the glandular portion; *t*, trachea. (This and Fig. 7 after Kliemensiewicz.)

Fig. 9. Eversible dorsal glands (*ev. gl*) of larva of *Orgyia leucostigma* in Stage II; *gc*, glandular cells at bottom of the crater-like depression; *m*, retractor muscle; *p*, poison gland-cells of the root of the seta (*s*); *c*, cuticula; *hyp*, hypodermis; *A*, portion of the cuticle and hypodermis enlarged.

Fig. 10. Lateral eversible gland of *Hyperchiria io*, Stage II; *rm*, retractor muscle; *oen*, œnocytes.

Fig. 11. The same as Fig. 10, but representing a section through one side of the eversible gland.

Fig. 12. *A*, end of body of *Colænis julia*; *ev*, eversible anal gland; *oa*, odoriferous appendages; *B*, the same in *Heliconius apseudes*, side view; *C*, odoriferous appendages of *Colænis dido* in fresh condition; *D*, tested with alcohol and benzine.

Fig. 13. Odoriferous appendages of *Heliconius eucrate*, head cleansed—(Figs. 12–13 after F. Müller.)

Fig. 14. Odoriferous glands (*ogl*) in the pupa of *Vanessa io*; *r*, rectum; *h*, the folds of hypodermis which forms the terminal papilla of the abdomen; *ov*, oviduct. (After Jackson.)